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Richie et al.

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(54) **MULTI CHAMBER MIXING MANIFOLD**

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This patent is subject to a terminal disclaimer.

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(22) Filed: **Sep. 29, 2015**

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(63) Continuation of application No. 14/487,733, filed on Sep. 16, 2014, now Pat. No. 9,144,775, which is a continuation of application No. 13/458,526, filed on Apr. 27, 2012, now Pat. No. 8,834,016.

(60) Provisional application No. 61/479,641, filed on Apr. 27, 2011.

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B01F 5/06	(2006.01)
B01F 3/08	(2006.01)

(52) **U.S. Cl.**
CPC ***B01F 5/0618*** (2013.01); ***B01F 3/0861*** (2013.01); ***B01F 15/0222*** (2013.01); ***B01F 15/0266*** (2013.01); *B01F 2005/0625* (2013.01); *B01F 2215/0081* (2013.01)

(58) **Field of Classification Search**
CPC . B01F 5/0604; B01F 3/0861; B01F 15/0222
USPC 366/134, 340
See application file for complete search history.

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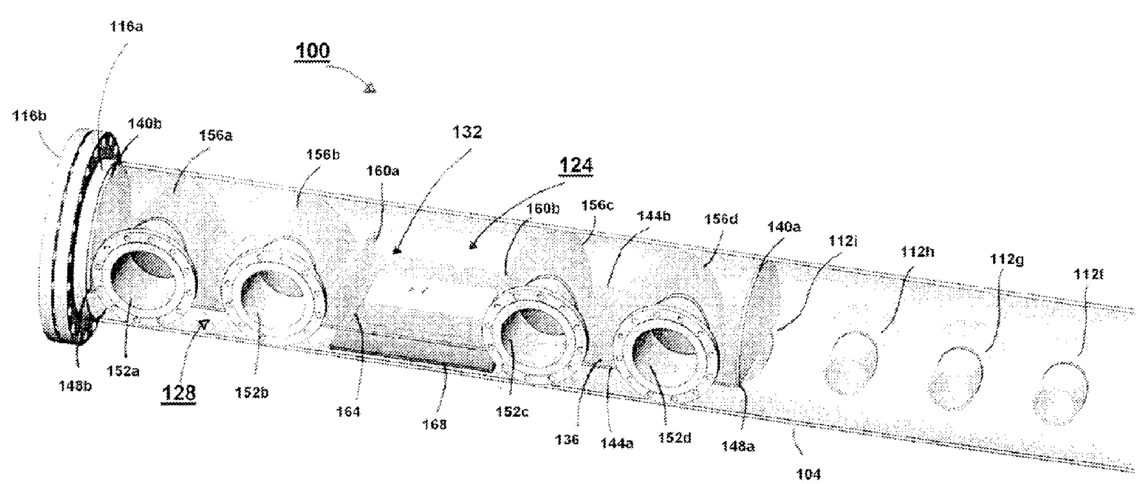
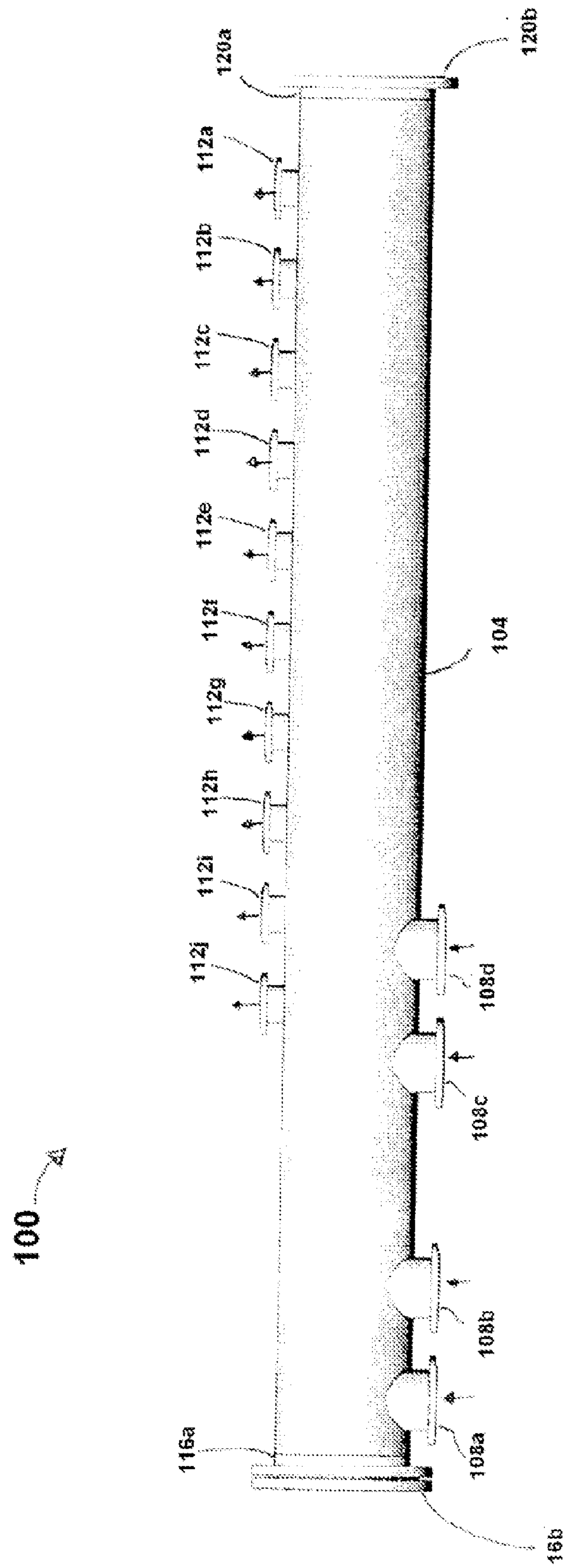
(57) **ABSTRACT**

One or more embodiments relate to systems and methods for mixing of two or more fluids using a multi-chamber manifold. One or more embodiments relate to optimal mixing.

15 Claims, 6 Drawing Sheets

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108b
108c
108d
112a
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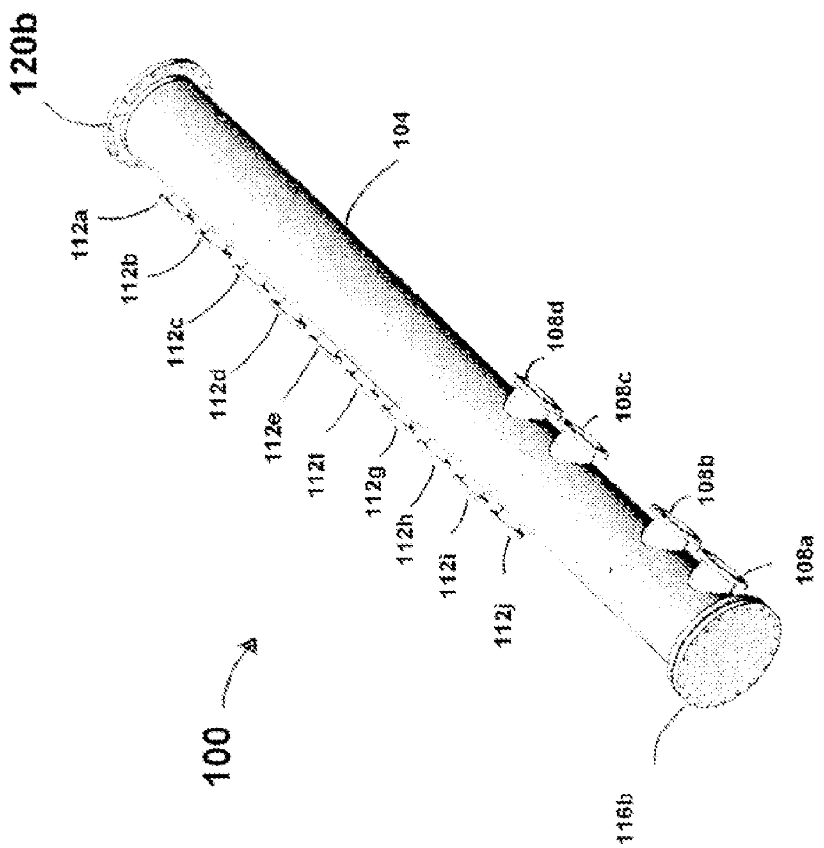
112g
112h
112i
112j
116a
116b
120a
120b

FIG. 1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112b
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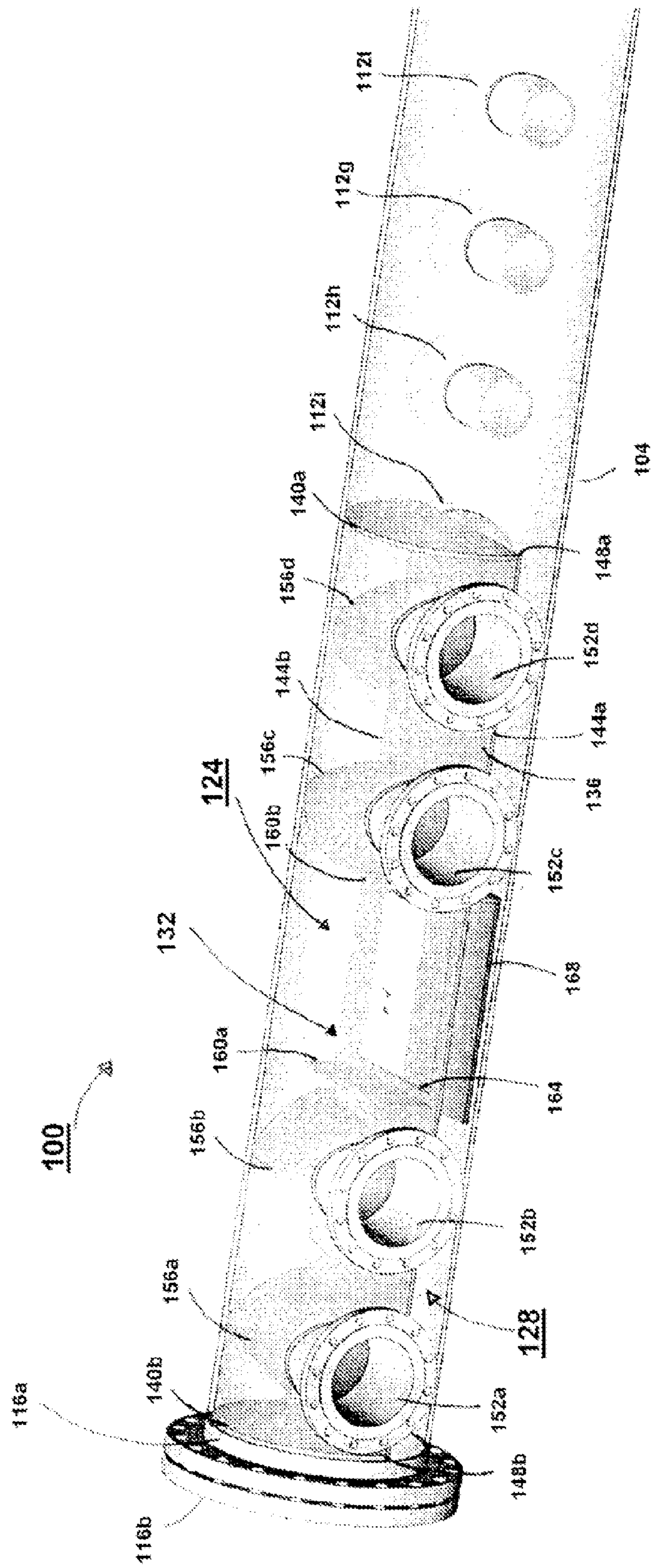
108a
100
116b

FIG. 2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148a
156d
152d
144b
144a
136
124
156c
160b
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132
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160a
164
100
156b
152b
128
156a
140b
116a
152a
148b
116b

FIG. 3

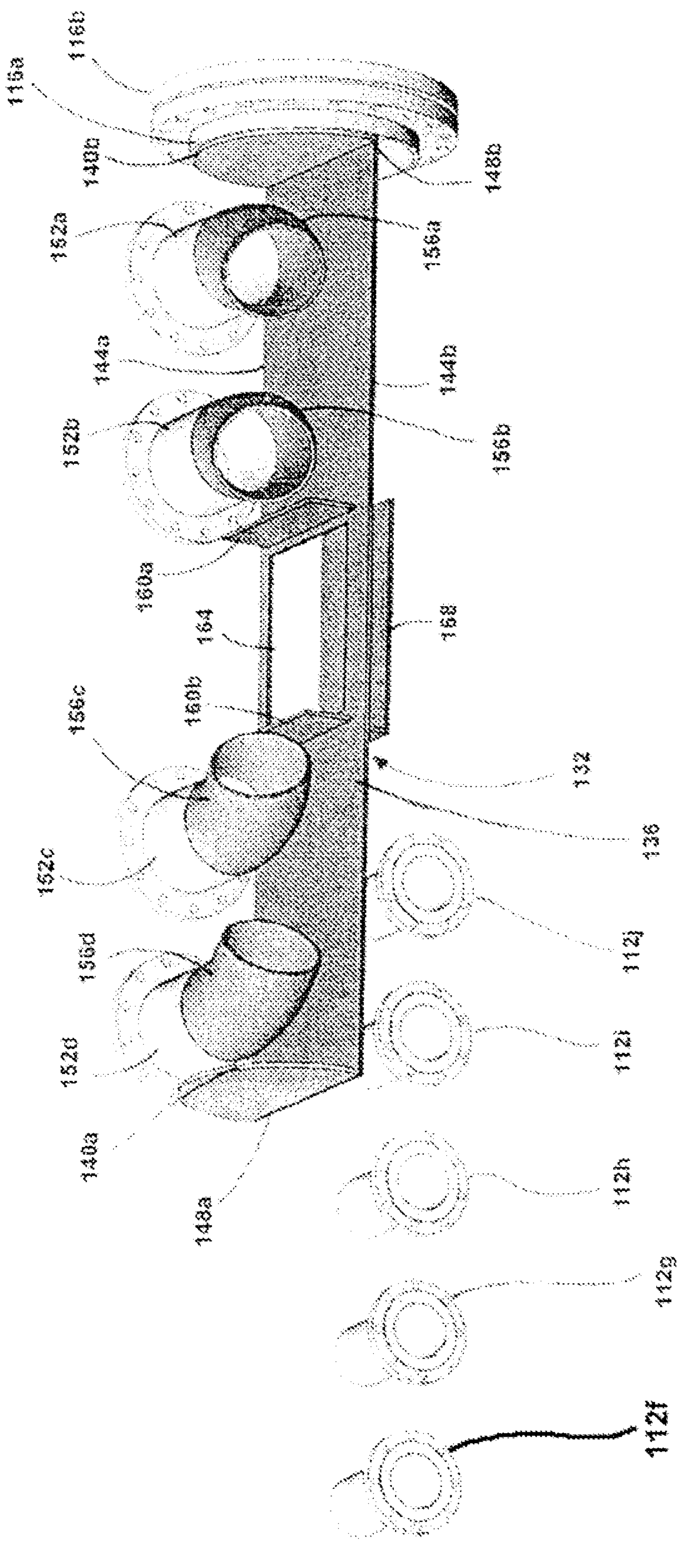
116b
116a
140b
148b
152a
156a
144a
144b
152b
156b
160a
164
168
156c
160b
132
136
152c
156d
112j
152d
112i
140a
148a
112h
112g
112f

FIG. 4

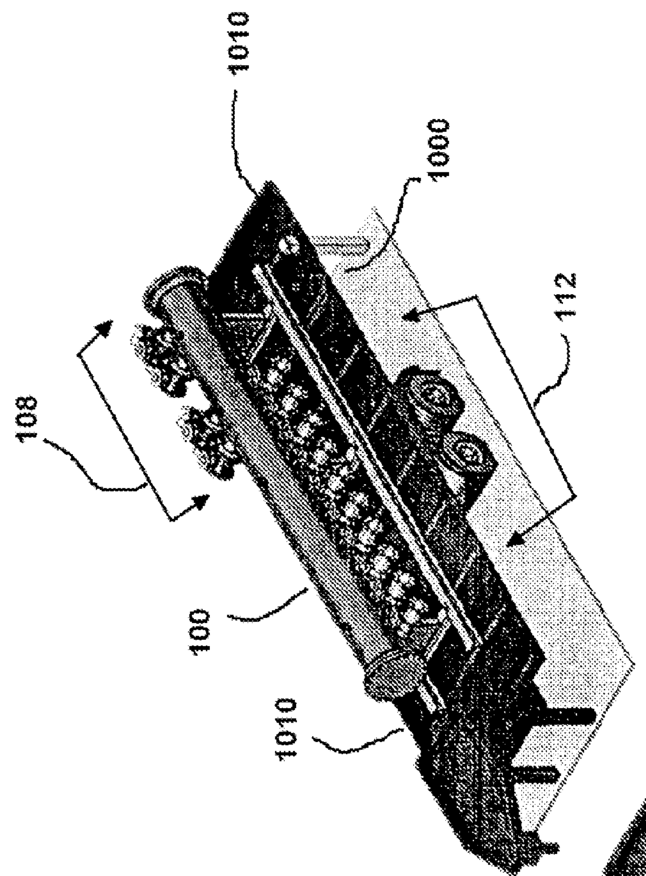

FIG. 6

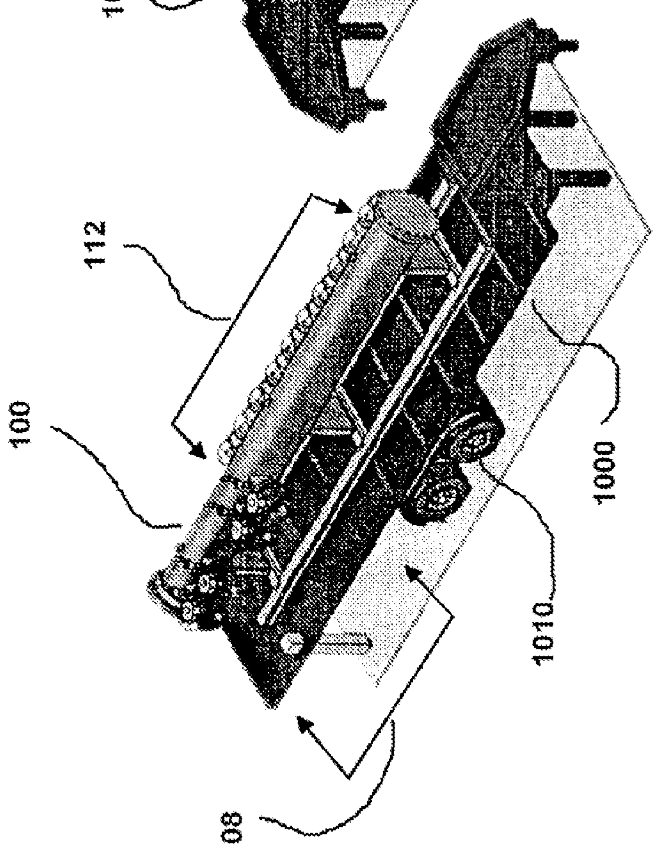

FIG. 5

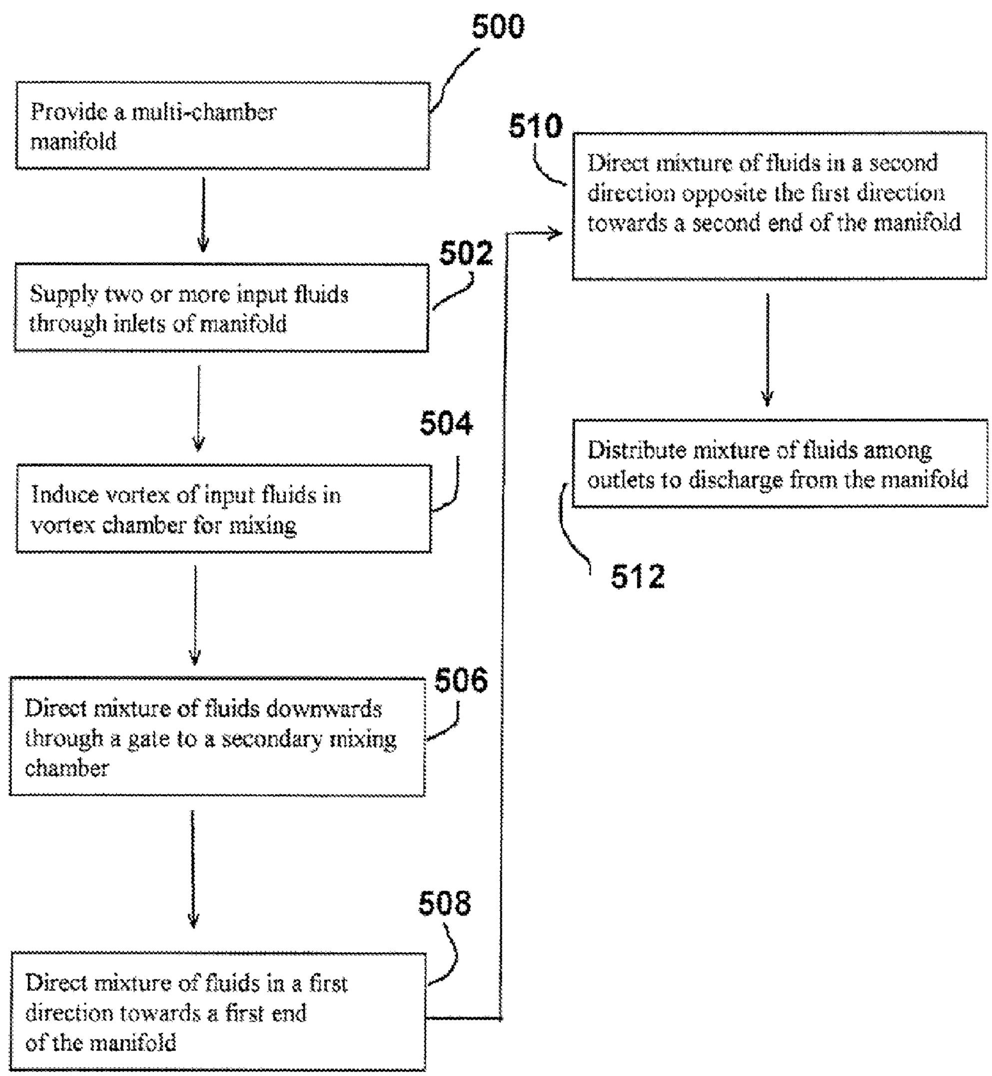
500
Provide a multi-chamber manifold
502
Supply two or more input fluids through inlets of manifold
504
Induce vortex of input fluids in vortex chamber for mixing
506
Direct mixture of fluids downwards through a gate to a secondary mixing chamber
508
Direct mixture of fluids in a first direction towards a first end of the manifold
510
Direct mixture of fluids in a second direction opposite the first direction towards a second end of the manifold
Distribute mixture of fluids among outlets to discharge from the manifold
512

FIG. 7

MULTI CHAMBER MIXING MANIFOLD

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation of U.S. patent application Ser. No. 14/487,733, filed on Sep. 16, 2014 (issuing as U.S. Pat. No. 9,144,775 on Sep. 29, 2015), which is a continuation of U.S. patent application Ser. No. 13/458,526, filed Apr. 27, 2012 (issued as U.S. Pat. No. 8,834,016 on Sep. 16, 2014), which claims benefit of U.S. Provisional Patent Application Ser. No. 61/479,641, filed on Apr. 27, 2011, each of which is hereby incorporated herein by reference, and priority of each is hereby claimed.

Priority of U.S. Provisional Patent Application Ser. No. 61/479,641, filed on Apr. 27, 2011, incorporated herein by reference, is hereby claimed.

BACKGROUND

One embodiment relates generally to systems and methods for optimal mixing and distribution of two or more fluids, and more particularly, to systems and methods for optimal mixing and distribution of two or more fluids, including fracturing (frac) fluids and completion fluids, used in oil and gas operations.

In a variety of applications, the proper mixing and distribution of two or more fluids is a critical performance-affecting factor.

Many conventional manifold designs provide insufficient mixing and/or distribution of the subject fluids. For example, one conventional manifold design comprises a first pipe having inlets disposed thereon arranged in a first linear array pattern. The first pipe is connected via one or more conduits to a second pipe disposed substantially parallel to the first pipe, the second pipe having outlets disposed thereon arranged in a second linear array pattern. Fluids injected through the inlets travel through the first pipe to the connecting conduits and then into the second pipe where the fluid can then exit through the outlets. This flow path would ideally provide the means by which the injected fluids can thoroughly mix before exiting the manifold.

However, a typical scenario results in the fluid(s) injected through the outermost inlets of the first linear array pattern (i.e., the inlets disposed closest to the ends of the first pipe) being substantially absent from the outermost outlets of the second linear array pattern (i.e., the outlets disposed closest to the ends of the second pipe) positioned on the opposite side. A fluid injected through an inlet at one end of the first pipe is unlikely to travel in a flow path in which it will make it to an outlet at the opposite end of the second pipe.

While certain novel features of this invention shown and described below are pointed out in the annexed claims, the invention is not intended to be limited to the details specified, since a person of ordinary skill in the relevant art will understand that various omissions, modifications, substitutions and changes in the forms and details of the device illustrated and in its operation may be made without departing in any way from the spirit of the present invention. No feature of the invention is critical or essential unless it is expressly stated as being "critical" or "essential."

SUMMARY

The apparatus of the present invention solves the problems confronted in the art in a simple and straightforward manner. What is provided is a multi chamber mixing chamber method and apparatus.

One or more embodiments of the invention provide systems and methods for optimal mixing and distribution of two or more fluids.

The drawings constitute a part of this specification and include exemplary embodiments to the invention, which may be embodied in various forms.

BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the nature, objects, and advantages of the present invention, reference should be had to the following detailed description, read in conjunction with the following drawings, wherein like reference numerals denote like elements and wherein:

FIG. **1** shows a top view of the exterior of a multi-chamber manifold in accordance with one or more embodiments of the invention.

FIG. **2** shows a rear perspective view of the exterior of a multi-chamber manifold in accordance with one or more embodiments of the invention.

FIG. **3** shows a perspective view taken from the right side of the rear interior portion of a multi-chamber manifold in accordance with one or more embodiments of the invention.

FIG. **4** shows a perspective view taken from the left side of the rear interior of a multi-chamber manifold in accordance with one or more embodiments of the invention.

FIG. **5** is a front perspective view (taken from the right side) showing the multi-chamber manifold of FIGS. **1-4** mounted on a skid which in turn is mounted on a trailer.

FIG. **6** is a front perspective view (taken from the left side) showing the multi-chamber manifold of FIGS. **1-4** mounted on a skid which in turn is mounted on a trailer.

FIG. **7** shows a flowchart illustrating a method in accordance with one or more embodiments of the invention.

DETAILED DESCRIPTION

Detailed descriptions of one or more preferred embodiments are provided herein. It is to be understood, however, that the present invention may be embodied in various forms. Therefore, specific details disclosed herein are not to be interpreted as limiting, but rather as a basis for the claims and as a representative basis for teaching one skilled in the art to employ the present invention in any appropriate system, structure or manner.

FIGS. **1-2** illustrate a top view and a perspective view, respectively, of the exterior of a multi-chamber manifold **100** in accordance with one or more embodiments of the invention.

The multi-chamber manifold **100** comprises an elongate housing **104** having a first end **116*a*** and a second end **120*a***. The ends **116*a***, **120*a*** may be sealably capped with blocking end flanges **116*b***, **120*b*** to prevent fluid from escaping therethrough. A plurality of fluid inlets **108*a*-108*d*** may be disposed along housing **104** in a first linear array pattern. Outermost fluid inlet **108*a*** may be disposed proximate the first end **116*a*** and the first linear array pattern may extend towards the second end **120*a***. A plurality of fluid outlets **112*a*-112*j*** may also be disposed along housing **104** in a second linear array pattern. Outermost fluid outlet **112*a*** may be disposed proximate the second end **120*a*** and the second linear array pattern may extend towards the first end **116*a***. Flow control valves (not shown) may be used to regulate fluid flow through the fluid inlets **108*a*-108*d*** and the fluid outlets **112*a*-112*j***. In one embodiment, carbon steel may be used to construct the multi-chamber manifold **100**. However, any material suitable for constructing a manifold for optimal mixing and distribution of two or more fluids may be used. While housing **104** is shown as having an annular cross-section, other configurations could be used in other embodiments.

Inlets **108***a*-**108***d* may each be connected to one or more sources of fluid so that at least two different types of fluid may be fed or supplied to the multi-chamber manifold **100** for mixing and distribution. The fluids may include liquids and gases. In one embodiment, the fluids may comprise frac water blends obtained from a plurality of sources, or mixtures of frac fluids, chemical additives, and brines. Methods for facilitating the delivery of optimal volumes of a frac fluid containing optimal concentrations of one or more additives to a well bore are disclosed in United States Patent Publication No. 2010/0059226 A1, which is incorporated herein by reference in its entirety. Where a definition or use of a term in the incorporated reference is inconsistent or contrary to the definition of that term provided herein, the definition of that term provided herein applies and the definition of that term in the reference does not apply. The systems and methods of the present invention may be used to provide a homogeneous fluid blend for use in conjunction with the incorporated reference.

Referring now to FIG. **3**, an inside view of housing **104** according to one or more embodiments of the present invention is shown. Within housing **104** of the multi-chamber manifold **100**, there may be provided a plurality of chambers. In one embodiment, the multichamber manifold **100** comprises two chambers: a primary mixing chamber **124** (referred to hereinafter as "vortex chamber **124**") and a secondary mixing chamber **128**.

As shown in FIGS. **3**-**4**, the vortex chamber **124** may comprise a chamber separation structure **132** separating the vortex chamber **124** from the secondary mixing chamber **128**. An upper portion of the inner wall of housing **104** may define upper and lateral boundaries of the vortex chamber **124**. The vortex chamber **124** may be disposed proximate the first end **116***a* of housing **104** such that the vortex chamber **124** may receive fluid entering the multi-chamber manifold **100** through the inlets **108***a*-**108***d*.

The chamber separation structure **132** may comprise a horizontal chamber separation plate **136** defining a lower boundary of the vortex chamber **124** and one or more vertical chamber separation plates **140***a*, **140***b* defining lateral boundaries of the vortex chamber **124**. The horizontal chamber separation plate **136** comprises side walls **144***a*, **144***b* that may be sealably coupled to the inner wall of housing **104**. The one or more vertical chamber separation plates **140***a*, **140***b* may be oriented substantially perpendicular to the horizontal chamber separation plate **136**. The one or more vertical chamber separation plates **140***a*, **140***b* may be disposed at and sealably coupled to the ends **148***a*, **148***b* of the horizontal chamber separation plate **136**. In one embodiment, a portion of vertical chamber separation plate **140***a* may be shaped to conform to the geometry of the inner wall of housing **104** so as to create a sealed barrier, preventing the fluid mixture inside the vortex chamber **124** from flowing laterally in a direction towards the second end of housing **120***a*.

Inlets **108***a*-**108***d* may protrude both outwardly and inwardly with respect to housing **104**, each outward-inward protrusion combination forming an inlet nozzle defining a passage through which a fluid may be injected to the vortex chamber **124**. The outwardly protruding portions **152***a*-**152***d* of the inlet nozzles allow for fluids to commence its flow path into the multichamber manifold **100** such that the fluids flow substantially radial to housing **104**. The inwardly protruding portions **156***a*-**156***d* of the inlet nozzles are angled to affect an angular velocity on the fluids, projecting the fluids into the vortex chamber **124** in a manner causing the fluids to swirl rapidly about a center. This induced swirl, or vortex, provides turbulent flow that facilitates thorough mixing of the injected fluids, producing a substantially homogeneous blend. The specific angle of each inlet nozzle is determined based on the particular application.

The chamber separation structure **132** may further comprise a plurality of baffle plates **160***a*, **160***b* that extend upwardly from and substantially perpendicular to the horizontal chamber separation plate **136**. As previously described, the inlet nozzles are angled to induce a vortex that facilitates the mixing of the injected fluids. The upwardly extending baffle plates **160***a*, **160***b* serve to guide the mixture of fluids through a gate **164** disposed between the upwardly extending baffle plates **160***a*, **160***b*, the gate **164** defining an opening in the horizontal chamber separation plate **136**. The gate **164** directs the mixture of fluids to flow to the secondary mixing chamber **128**.

One or more inlet nozzles may be disposed at either side of the upwardly extending baffle plates **160***a*, **160***b*. For example, in one embodiment, a first set of two inlet nozzles may be disposed at a lateral distance from upwardly extending baffle plate **160***a*, proximal to the first end **116***a* of housing **104**. In this configuration, a second set of two inlet nozzles may also be disposed at a lateral distance from upwardly extending baffle plate **160***b*, distal to the first end **116***a* of housing **104** relative to first set of inlet nozzles. The inwardly protruding portions **156***a*-**156***d* of the inlet nozzles may be angled upward relative to the horizontal chamber separation plate **136** and inward relative to the one or more vertical chamber separation plates **140***a*, **140***b*. Thus, the two sets of inlet nozzles may provide a mirror image trajectory of vectored fluid flow allowing the fluids to coincide and induce the vortex above the gate **164**. Gravity causes substantially all of the fluid mixture to flow downwardly through gate **164**, guided, in part, by upwardly extending baffles **160***a*, **160***b*.

The chamber separation structure **132** may further comprise an L-shaped baffle plate **168** connected to the bottom surface of the horizontal chamber separation plate **136** and disposed below the gate **164**. Upon passing through gate **164**, the fluid mixture encounters the L-shaped baffle plate **168**, which guides the fluid mixture flow in a first direction towards the first end **116***a* of housing **104**. The change in flow direction of the fluid mixture caused by the L-shaped baffle plate **168** may further enhance the mixture quality.

Another change in flow direction is caused by the fluid mixture encountering the first end **116***a* of housing **104**, which forces the fluid mixture to flow in a second direction opposite the first direction. This change in flow direction may also further enhance the mixture quality. Moreover, as the fluid mixture flows in the second direction, it flows past the L-shaped baffle plate **168** towards the second end **120***a* of housing **104** where the fluid mixture can then be evenly distributed among fluid outlets **112***a*-**112***j*.

Although FIGS. **3**-**4** show multi-chamber manifold **100** having two chambers (vortex chamber **124** and secondary mixing chamber **128**), it is envisioned that other embodiments may have additional chambers for further mixing. A secondary spill over plate (not shown) may be incorporated in the secondary mixing chamber **128** in order to capture solids or perform a two-stage fluid separation prior to the fluid mixture exiting through outlets **112***a*-**112***j*. For example, in one or more embodiments, a two-stage fluid separation may involve the separation of oil and water.

The multi-chamber manifold **100** illustrated in FIGS. **1-4** may be designed and constructed to be lightweight, compact, and portable. In one or more embodiments of the invention, the multi-chamber manifold **100** may be mounted on a trailer, truck, or any other suitable vehicle for transporting the manifold **100** to various work sites. However, in other embodiments of the invention, the manifold **100** may be fixed to a particular location.

One or more embodiments of the present invention relate to methods for enhanced mixing of fluids, as shown by the flow chart in FIG. **5**. The methods involve providing a multichamber manifold **500**, the manifold comprising a housing, a plurality of fluid inlets, a plurality of fluid outlets, a vortex chamber, and a secondary mixing chamber.

The methods further involve supplying two or more input fluids to the manifold through the fluid inlets of the manifold **502**. The fluids may flow through inlet nozzles and into the vortex chamber. The fluid nozzles may be angled to induce a vortex in the vortex chamber **504**. The vortex serves the purpose of stirring the input fluids for thorough mixing, producing a fluid mixture.

The fluid mixture may be directed downwards from the vortex chamber through a gate to a secondary mixing chamber **506** for further mixing. Baffles may be used to guide the flow path of the fluid mixture in various directions. The fluid mixture may be directed in a first direction towards a first end of the manifold **508**. The fluid mixture may also be directed in a second direction opposite the first direction towards a second end of the manifold **510**. Changing the direction of the fluid mixture flow path facilitates further mixing of the fluids.

The resulting homogeneous fluid blend may be distributed among the plurality of fluid outlets to discharge from the manifold **512**. The destination of the fluid mixture after discharging from the manifold depends on the particular application. Fluid flow can be directed in its entirety to one destination or distributed either evenly or proportionally to multiple destinations.

It is to be understood that the invention is not to be limited or restricted to the specific examples or embodiments described herein, which are intended to assist a person skilled in the art in practicing the invention. For example, the number of fluids to be mixed, the number of inlets, the number of outlets, the number of spill over plates, and the number of chambers may vary according to the desired results of a particular application. Also, the dimensions of the various components of the multi-chamber manifold may be scaled to achieve the desired results of a particular application. Accordingly, numerous changes may be made to the details of procedures for accomplishing the desired results. These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the spirit of the present invention disclosed herein and the scope of the appended claims.

The following is a list of reference numerals:

LIST FOR REFERENCE NUMERALS

(Part No.)	(Description)
100	multi-chamber manifold
104	elongate housing
116a	first end 116a
120a	second end
116b	blocking end flange
120b	blocking end flange

-continued

LIST FOR REFERENCE NUMERALS

(Part No.)	(Description)
108	fluid inlets (108a-108d)
112	plurality of fluid (outlets 112a-112j)
124	a primary mixing chamber (vortex chamber)
128	secondary mixing chamber
132	chamber separation structure
136	horizontal chamber separation plate
140a	vertical chamber separation plate
140b	vertical chamber separation plate
144a	side wall
144b	side wall
152	outwardly protruding portions (152a-152d) of the inlet nozzles
156	inwardly protruding portions (156a-156d) of the inlet nozzles are angled to affect an angular velocity on the fluids
160a	baffle plate
160b	baffle plate
164	gate
168	L-shaped baffle plate
500	step of providing a multichamber manifold
502	step of supplying two or more input fluids to the manifold
504	step of inducing a vortex in the vortex chamber 504
506	step of directing fluids from the vortex chamber to a secondary mixing chamber
508	step of directing the mixture of fluids in a first direction towards a first end of the manifold
510	step of directing mixture of fluids in a second direction, which second direction is substantially the opposite direction as the first direction, and towards a second end of the manifold
512	step of distributing the mixture of fluids among outlets to discharge from the manifold

All measurements disclosed herein are at standard temperature and pressure, at sea level on Earth, unless indicated otherwise. All materials used or intended to be used in a human being are biocompatible, unless indicated otherwise.

It will be understood that each of the elements described above, or two or more together may also find a useful application in other types of methods differing from the type described above. Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention set forth in the appended claims. The foregoing embodiments are presented by way of example only; the scope of the present invention is to be limited only by the following claims.

The invention claimed is:

1. A mixing chamber comprising:

(a) an elongated body having first and second ends, an exterior wall with an interior having first and second chambers, and a plurality of inputs and at least one output;

(b) the first chamber and second chamber being fluidly connected to each other;

(c) the plurality of inputs entering the first chamber and the plurality of outputs exiting from the second chamber;

(d) the plurality of inputs being directed toward each other; and

(e) wherein separating the first and second chambers is a dividing structure, which dividing structure includes a first plate and second plate, the dividing structure having a gate opening located in the second plate.

2. The mixing chamber of claim **1**, wherein there are one or more baffles next to the gate opening.

3. The mixing chamber of claim **2**, wherein one or more baffles extend above the gate opening and one or more baffles extend below the plate.

4. A mixing chamber comprising:

(a) an elongated housing having a housing length, a first upstream and a second downstream end portion and a side wall surrounding an interior;

(b) the interior having a dividing structure that divides the interior into primary and secondary chambers;

(c) the dividing structure including a first plate that connects to the body side wall at a position in between the body end portions, the first plate extending over only a part of the cross section of the housing;

(d) the dividing structure including a second plate that extends from one end portion of the housing a partial distance of the housing length and connecting with the transverse plate;

(e) a first mixing chamber formed by the first plate, the second plate, and a portion of the side wall, the first mixing chamber extending a distance along the length of the housing;

(f) a second mixing chamber that is longer than the first mixing chamber, the second mixing chamber having a portion that contacts the second plate;

(g) multiple inlets through the side wall that enable fluid to be added to the first mixing chamber;

(h) outlets in the side wall that enable fluid discharge from the second chamber; and

(i) the longitudinal plate having a gate that enables fluid flow from the first chamber to the second chamber.

5. The mixing chamber of claim **4** wherein some of the inlets are on opposing sides of the gate.

6. The mixing chamber of claim **4**, wherein the gate is in between two of said inlets.

7. The mixing chamber of claim **4**, wherein the elongated body has a longitudinal length including first, second, and third longitudinal portions, each longitudinal portion being of equal length, with the second portion being between the first and third portions, and the first plate is positioned in the second portion.

8. The mixing chamber of claim **6**, wherein there are outlets on the upstream side of the first plate.

9. The mixing chamber of claim **6**, wherein some of the outlets are in between the first plate and one of the inlets.

10. The mixing chamber of claim **4**, wherein all of the inlets are between the first plate and the first end portion of the body.

11. The mixing chamber of claim **4**, wherein some of the inlets include an elbow shaped fitting.

12. The mixing chamber of claim **4**, wherein a majority of the inlets are in between the first plate and the second end portion of the body.

13. The mixing chamber of claim **4**, wherein at least one of the elbow shaped fittings discharges flow toward the gate.

14. The mixing chamber of claim **4**, wherein multiple of the elbow shaped fittings discharge flow toward the gate.

15. A mixing chamber comprising:

(a) an elongated housing having a housing length, a first upstream and a second downstream end portion and a side wall surrounding an interior;

(b) the interior having a dividing structure that divides the interior into primary and secondary chambers;

(c) the dividing structure including a first plate that connects to the body side wall at a position in between the body end portions, the first plate extending over a part of the cross section of the housing;

(d) the dividing structure including a second plate that extends from one end portion of the housing a partial distance of the housing length and connecting with the transverse plate;

(e) a first mixing chamber formed by the first plate, the second plate, and a portion of the side wall, the first mixing chamber extending only a partial distance along the length of the housing;

(f) a second mixing chamber that is longer than the first mixing chamber, the second mixing chamber having a portion that contacts the second plate;

(g) one or more inlets through the side wall that enable fluid to be added to the first mixing chamber;

(h) outlets in the side wall that enable fluid discharge from the second chamber, one or more of said outlets being downstream of said first plate; and

(i) the second plate having a gate that enables fluid flow from the first chamber to the second chamber.

* * * * *